



A Consideration of Constraints on Aircraft Departure Operations

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EXECUTIVE SUMMARY

Today's air traffic system safely supports a large number of operations to and from airports throughout the country, making air travel a regular feature of the commercial and leisure activities of people throughout the United States. In large metropolitan areas, referred to as metroplexes, multiple airports often compete directly for passenger revenues on schedule and flight frequency. However, as the air traffic system is stressed by demand, airlines are failing to meet air travelers' expectations for on-schedule performance. Because metroplex operational capabilities play a significant role in overall air traffic system capacity and delay production, reducing capacity constraints and delays associated with metroplex operations is viewed as a critical component of increasing the capacity of the air transportation system as a whole.

This paper presents a system-level perspective on the operational issues and constraints that limit departure capacity at large metropolitan airports in today's air transportation system. It examines the influence of constraints evident in en route airspace, in metroplex operations, and at individual airports from today's perspective and with a view toward future gate-to-cruise operations. Cross-cutting organizational and technological challenges are discussed in relation to their importance in addressing the constraints.

As input to this paper, a wide range of aviation stakeholders were consulted, including aviation researchers, air traffic system and airport planners, air traffic operations and control personnel, systems and network analysts, aviation union and trade representatives, and academic and other aviation subject matter experts. Literature was gathered and reviewed, including air traffic system regulations, standard operating practices, and transformation plans, along with research results and data to help characterize current and future departure operations. This provided a comprehensive basis for consideration of metroplex departure operations and was used to draw conclusions regarding constraints and potential solutions for enhancing the capacity of metroplex departure operations.

This paper presumes that the air transportation system has a singular goal: to facilitate safe and efficient aircraft movement. It asserts that the elements of the system through which aircraft movements occur comprise a network whose productivity is limited by its least productive elements and that system productivity can only be increased by applying resources to the most constrained elements within the system.

The issues and constraints associated with gate-to-cruise (departure) operations are presented within the hierarchy of en route, metroplex, and individual airport environs, with approaches to increase departure capacity within each area identified. The hierarchy is in rank order, from greatest to least, of the constraint each of these environs presently imposes on departure productivity, and is consistent with the order in which the constraints must be

addressed in order to achieve any significant benefit in terms of departure productivity. Many of the issues and constraints identified in this paper have underlying organizational or technical challenges that span multiple operational phases; these are also identified.

Focusing the approach on the goal of aircraft movement resulted in the conclusion that departure productivity is presently artificially constrained within the en route sector by centralized, systemic policies and practices that unnecessarily limit productivity. The en route constraints are real, in that they truly affect operations, but are artificial in that they are largely unnecessary given the potential productivity of en route airspace based on existing technologies and procedures available today.

Metroplex constraints result from shared resource limits and are mostly real, in that most cannot currently be addressed using technologies and procedures available today. Wherever possible, solutions that provide for independence between metroplex operations should be implemented. Decoupling metroplex operations provides the greatest potential to increase system productivity; application of technologies with the potential to reduce airspace volumetric requirements would significantly alter metroplex dependencies and could significantly increase departure capacity. Where this is not possible, solutions that maximize the productivity of shared resources should be implemented.

Airports are where system productivity is realized; they have real, unique operational constraints that are affected by, and affect, their physical infrastructure. If the artificial constraint imposed by en route airspace management practices is removed, and metroplex operations are made independent wherever possible, airports will ultimately constrain departure productivity. Airspace design solutions that address metroplex dependencies will help to reduce related constraints at individual airports. Protection of airspace is critical to supporting future operational concepts. Solutions that improve surface operations and gate management are needed to increase departure, and thereby airport, productivity.

This paper ultimately concludes that applied research and development should focus on increasing metroplex departure capacity by eliminating shared resource constraints rather than attempting to improve upon current practices. It suggests that research is required to better understand metroplex constraints, to determine minimum total loss concepts associated with shared resources, and to develop and implement solutions that increase the productivity of shared resources within metroplexes through organizational changes and the implementation of aircraft and air traffic system technologies.

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INTRODUCTION

This paper presents a system-level perspective on the operational issues and constraints in today's air transportation system, with a focus on those that limit departure capacity at large metropolitan airports. These airports are often in close proximity to other airports, creating a 'metroplex', defined for the purposes of this work as: *a group of airports that operationally interact through shared resources which limit operational capabilities*. This paper also presents a summary of selected prior and ongoing research dedicated to metroplex operations, and air transportation system modernization plans in the area of metroplex departure operations. For this paper, the consideration of metroplexes was limited to capacity-limited, large metropolitan area airports that regularly experience air traffic delays. Departure operations include the phases of flight from pushback from the gate to cruise flight.

Today's air traffic system safely supports a large number of operations to and from metropolitan and other airports throughout the country, making air travel a regular feature of the commercial and leisure activities of people throughout the United States. In large metropolitan areas, multiple airports often compete directly with each other for passenger revenues on schedule and flight frequency. However, as the air traffic system is stressed by the demand created for air transportation services, airlines at these airports are failing to meet air travelers' expectations for on-schedule performance. Because metroplex operational capabilities play a significant role in overall system capacity and delay production, reducing capacity constraints and delays associated with metroplexes is generally viewed as a critical component to increasing the capacity of the air transportation system as a whole. Metroplex airports could, in theory, be operated in a synergistic manner. In practice, however, they impose constraints on each other, decreasing capacity and efficiency at one or all of the airports. The purpose of this paper is to provide an understanding of metroplex departure operations issues and constraints and to identify opportunities to increase metroplex capacity and reduce delay.

The work underlying this paper is focused on developing research road maps for NASA's Airportal Project. As input to the development process, a wide range of aviation stakeholders were consulted, including researchers working in the NASA Airspace Systems Program under both the NextGen Airportal and NextGen Airspace Projects, FAA air traffic system and airport planners, FAA operations and air traffic control personnel, systems and network analysts, academic and other aviation subject matter experts, and aviation union and trade representatives. Coincident with these meetings, literature pertaining to air traffic system operations was gathered and reviewed, including existing regulations and standard operating practices, future planning, research, and data to help characterize current and future departure operations. The information gathered provided a comprehensive overview of metroplex departure operations and was used to draw conclusions regarding constraints and potential solutions for enhancing the capacity of metroplex departure operations.

This paper first frames the problem and presents a view of future gate-to-cruise operations. It then examines the influence of constraints evident in en route airspace, in metroplexes, and at individual airports. The cross-cutting challenges of organization and technology are discussed in relation to their importance in addressing these constraints. Finally, key conclusions are provided, which were drawn from the discussions, data, and research documented herein. Supporting appendices catalog and classify metroplex issues and constraints identified through stakeholder interaction, detail typical departure operations from pre-pushback through top of climb, provide an acronym list, and review prior and current research on

metroplex departure operations along with research and development plans for concepts to address metroplex constraints. A bibliography is provided in addition to footnoted references.¹

Problem Statement

The goal of the air transportation system is to facilitate safe and efficient aircraft movement from one airport to another. The elements of the system through which aircraft movements occur comprise a network whose productivity is limited by the least productive elements within it. Therefore, system productivity can only be increased by addressing the most constrained elements of the system. In managing the operation and evolution of the system, investing in non-constraining elements will not make the system more productive if the most constraining elements are not addressed.

Understanding the constraints within the air traffic system is critical to making improvements in its productivity. Given the complexity of the air traffic system, and operations, it is difficult to accurately define clear operational cause and effect relationships. Maintaining a goal-oriented perspective helps to identify constraints and their underlying causes, and to focus directly on solutions. With a focus on the goal of aircraft movement, the constraints within the air traffic system become more readily identifiable.

A number of air transportation system researchers believe that the domestic air traffic system behaviors can best be characterized and understood using network theories. The U.S. air traffic system, by its nature, exhibits large scale stochastic behaviors; it does not exhibit deterministic behaviors often assumed by network theories. The limitations and removal of degrees of freedom from air traffic operations have contributed to the unprecedented levels of delay and inefficiency in today's system. Further attempts to force the system to behave deterministically are unlikely to yield the increased capacity needed in future years. Unfortunately, many of today's plans for changes to the system continue on a path toward excision of freedoms from the system in a continuing attempt to design deterministic behaviors into the future system.

Metroplex airports exist within the context of the air traffic system as both individual airports and as groups of airports sharing resources such as airspace and air traffic management. This system context was used to examine the constraints placed on the goal of aircraft movement by en route operational factors, by metroplex specific factors, and by individual airport factors. This hierarchy was selected to coincide with operational boundaries within air traffic management, as well as with the separation of responsibilities between the NextGen Airspace and NextGen Airportal research projects. Overarching this hierarchy is the consideration of the goal of aircraft movement and the identification of the most constraining aspect of both current operations and those planned for the future.

GATE-TO-CRUISE ISSUES AND CONSTRAINTS

This section presents the issues and constraints imposed on gate-to-cruise departure operations within the hierarchy of en route, metroplex, and individual airports, and discusses what can be done to increase departure capacity within each.

The factors that affect the efficiency of air traffic operations and their management are manifested in airspace, airport infrastructure, policy, procedures, organizational culture,

¹ This perhaps unorthodox reference method was used to acknowledge the diffuse affect of items listed in the bibliography on the thinking underlying this paper, while crediting specific ideas drawn from footnoted references.

technology, and human behavior, among others. Many of the factors are outside the realm of traditional NASA research, but many can be addressed through research and development activities. The interaction with aviation stakeholders described in the introduction produced a wide-ranging list of issues and constraints associated with metroplex operations. Only a subset of these issues is discussed in this report. The consideration of literature described in the introduction informed the discussions and conclusions in this paper, but was not used to expand the issues and constraints list developed from stakeholder input. The complete list of issues and constraints provided by stakeholders is presented in Appendix A.

To aid in examining gate-to-cruise operations, a task list was developed detailing pre-departure through en route integration considerations for a typical commercial operation from a metroplex airport. The tasks involve airline operations center, maintenance, dispatch, flight crew, clearance delivery, ramp control, ground control, air traffic control tower, Terminal Radar Approach Control (TRACON), and Air Route Traffic Control Center (ARTCC) interactions. The list aided in gathering information from the aviation stakeholders consulted, and in categorizing and classifying the information provided into a list of issues and constraints for metroplex operations. This task list is incorporated for reference as Appendix B.

The following discussions, beginning with en route, and continuing to metroplex, and then to airports is in rank order, from greatest to least, of the constraint each of these presently imposes on departure productivity. This ordering is also consistent with the order in which the constraints must be addressed in order to achieve any significant benefit in terms of departure, and consequently, system productivity.

En route

The primary constraint on departure operations lies in the en route sector of the air traffic system. En route airspace² is the ultimate shared resource within the air traffic system, through which nearly all aircraft transition when moving from one airport to another. The way in which the en route portion of the air traffic system is operated creates artificial capacity restrictions which fail to meet demand. The primary causes for this are the use of fixed routes along which air traffic is constrained, and the procedures used to manage aircraft movement along these routes.

Today's en route airspace environment is characterized by fixed routes to which air traffic controllers restrict aircraft trajectories. The route structure does not serve point to point navigation, nor is it designed to segregate traffic flows to and from different airports. Rather, the existing route structures integrate traffic from many different airports across wide geographic areas onto a limited number of routes. The existing routes force aircraft into single file lines of traffic over long distances, adding significant distance when compared to the direct distance between airports. The route structure fails to reliably accommodate the demand present in today's system. The route structure is based primarily on navigation over and between terrestrial navigation beacons, originally providing for navigation in instrument conditions. Technologies available today permit reliable, safe, point to point navigation, making indirect, fixed routes inefficient. The potential capacity of the en route airspace is far greater than that realized by today's system; in fact, the vast majority of en route airspace is seldom used. The practice of restricting aircraft to prescribed routes, and the procedures used to do so, results in unnecessary

² For the purposes of this paper en route airspace is considered to include Class A Airspace Areas and Class E Airspace Areas including En Route Domestic Areas, the Federal Airways, and Offshore/Control Airspace Areas as defined in JO7400.2G, effective 10 April 2008, Part 4, Chapter 14, Section 14-1-2.3

limitations on system productivity. The fact that the en route airspace acts as a primary constraint on the productivity of the system is demonstrable from multiple perspectives.

If en route airspace capacity exceeded demand, there would be no reason to limit opportunities for entry onto the routes or into en route airspace. However, in today's system aircraft are restricted for release into en route airspace using a variety of measures. For instance aircraft departing to busy metropolitan airports are issued an Expect Departure Clearance Time (EDCT). EDCTs are issued by en route air traffic managers and represent the time at which an aircraft is supposed to arrive at its departure runway and be issued a takeoff clearance. Departure restrictions such as miles-in-trail or EDCTs are predicated on the integration of flights into en route airspace at a limited set of points along prescribed routes or at the destination airport. Based on an EDCT, airline operations, dispatch, aircrew, and local controllers manage a flight's activities and impose delays upon it or others to meet EDCTs. The fact that terminal area and tower controllers are not directly involved in determining departure opportunities demonstrates the degree to which en route planning exercises control over departure operations. Centralized flow control management practices employed in recent years through the FAA's Air Traffic Control System Command Center (ATCSCC) also impose departure limits in response to the en route portion of the system failing to meet demand.

This degree of control is wholly inconsistent with the potential productivity of en route airspace given the technologies available today. If en route operations permitted more flexible use of the airspace, aircraft would not need to be restricted by centrally determined demand reduction measures, and the disruptions caused by doing so would be eliminated.

If en route airspace capacity exceeded demand, the airports in the air traffic system could operate without delay at the capacity supported by local resources. Unfortunately, many of the nation's largest airports regularly suffer delays and aren't currently operating at their expected, individual capacity. If en route airspace capacity exceeded demand, and local resources were increased, the capacity of the airport would increase, reducing delays created by demand exceeding capacity. However, expansion efforts at some of the busiest metropolitan airports are failing to yield increased capacity and reduced delay. For example, Dallas Fort Worth International Airport (DFW) completed a major capacity expansion effort in 1996 that included commissioning a new runway and redesigning local airspace to permit triple and quadruple independent arrival operations. The undertaking was projected to increase the maximum arrivals per hour from 66 to 108, and 102 to 146 under IFR and VFR conditions, respectively. However, delay at DFW following this major capacity enhancement effort actually increased.³ The more recent commissioning of a new runway at Atlanta Hartsfield International Airport (ATL) resulted in similar failures to meet increased capacity and delay reduction goals. These outcomes provide reason to question whether the current expansion effort at Seattle Tacoma International Airport, will meet capacity enhancement and delay reduction expectations, and, in general, argues against making changes to airports, especially in light of the costs for such projects⁴. If airport capacity constraints were the primary limiting factor in today's air transportation system, airports would be operating to their full potential, and expansion efforts would result in increased capacity and fewer delays.

The capacity of en route airspace could be significantly increased by eliminating the air traffic management practice of restricting aircraft to fixed routes, which could potentially

³ Hansen, Mark, Wenbin Wei, 1998 Multivariate Analysis of the Impacts of NAS Investments: A Case Study of a Major Capacity Expansion at Dallas-Fort Worth Airport. Institute of Transportation Studies University of California at Berkeley

⁴ Airport runway project costs at major airports have risen to more than a billion dollars

eliminate the constraint that en route airspace places on airport operations. Making better use of existing aircraft capabilities to conduct area navigation (RNAV) operations would permit aircrews to navigate from any point to another, while applying individual preferences to their navigation solutions. RNAV capabilities have been available to pilots since the 1960s. The FAA implemented RNAV as fixed high-altitude routings in the 1970s, only to revoke them in 1983 because operators chose not to be unnecessarily constrained to fixed routes, preferring to fly point to point. In 2003, the FAA again established RNAV routes,⁵ and they continue to propose adding RNAV routes.⁶ As discussed, the use of fixed routes unnecessarily restricts capacity, and the use of RNAV, or any other technology, to perpetuate the constraint of aircraft to fixed routes fails to address the capacity restrictions created by their use.

Operating the en route airspace in a manner that takes advantage of advanced aircraft capabilities will continue to require measures to ensure the safe separation of aircraft from each other and from the wake vortices they generate, and work will need to be done in the area of air traffic management tools supporting air traffic controllers and managers to take advantage of the full range of existing aircraft capabilities.

Work that focuses on distributed, tactical solutions is needed to address conflict detection and resolution and other issues. Distributed, tactical solutions will provide scalable, flexible air traffic system capacity, when compared to centralized management of local constraints. Complimentary, possibly redundant functions on-board aircraft and in air traffic management systems must be implemented, such that these capabilities are implemented robustly.

Metroplex

Given that the air transportation system is a network, addressing en route limitations will necessarily have implications for other elements of the system. If en route operational practices no longer constrained departure productivity metroplexes would. Improving productivity would then require that constraints associated with metroplexes be addressed. Within the NAS, shared resources cannot be used simultaneously; operations must be conducted sequentially, with conflicts resolved by forcing one or more and potentially all operations to be conducted at other than the desired time. Resolving temporal conflict overwhelmingly produces delay.

The elimination of shared resource dependencies in each metroplex would decouple the metroplex airports. For some metroplexes, fully decoupling the interdependencies between geographically close airports may not be possible because of their relative geometries, or other factors. Research is required to better understand metroplex constraints, to determine minimum total loss concepts associated with shared resources, and to develop and implement solutions that either decouple metroplex airports, or increase the productivity of shared resources within metroplexes.

Current practices for estimating capacity and managing capacity deficiencies often result in lost capacity. NextGen concepts⁷ may introduce improved coordination measures that could reduce lost capacity, but research is required to better understand how capacity is lost and to develop and implement solutions that improve capacity estimation and the responses to capacity deficiencies in order to limit lost capacity.

⁵ See “Establishment of Area Navigation Routes (RNAV)” Final Rule, Federal Register, Vol. 68, No. 90, page 24864

⁶ See “Proposed Establishment of Low Altitude Area Navigation Route (TRoute); Houston, TX” NPRM, Federal Register Vol. 73, No. 128, page 37905

⁷ See Appendix D for information on NextGen concepts and gate-to-cruise research

Resources typically shared by metroplex airports include airspace and air traffic management elements. Examples of metroplex constraints include the use of common fixes for arrivals and departures, the routing of arrival and departure flows in conflict with each other (generally caused by local metroplex geometries), and airspace sectors which require frequent coordination between controllers and limit operational maneuvering volumes. Each of these represents an area in which research and development activities could be focused.

In addressing metroplex issues and constraints, the primary objective should be to eliminate shared resource dependencies, and by doing so, decouple the airports and eliminate metroplex constraints. It would then be possible to focus on the issues and constraints unique to each airport. Only when it is clearly not possible to eliminate shared resource dependencies should solutions be sought that continue to share the resources.

The NY/NJ metroplex may not be able to eliminate resource sharing. Often, operational considerations for one airport of a metroplex dominate operations throughout the metroplex. For instance, in the NY/NJ metroplex, during periods of strong southeasterly winds, the operational configuration required at Kennedy (JFK) forces La Guardia (LGA) to change its operational configuration. If possible, operations at Newark (EWR) are segregated from JFK and LGA operations, generally with procedures associated with established airspace boundaries. Operations at the reliever airports of Teterboro, NJ (TEB) and at the small commercial hub airport, Westchester County (HPN), also significantly affect, and are affected by, operations at the three NY/NJ large hub commercial airports.

Terminal area airspace is a finite resource, whether associated with metroplex or single airports. To arrive and depart safely, aircraft must maintain alignment with runways when near the ground. Environmental considerations may require low altitude operations to overfly areas compatible with the noise generated by aircraft operations. The standards for arrival, departure, and other flight procedures require specific airspace volumes to safely separate aircraft. These standards are predicated on being able to prevent aircraft accidents in the presence of the cumulative uncertainties of communication, navigation, and surveillance (CNS) systems and procedures, coupled with the hazard presented by wake turbulence. Better use of existing technologies which reduce these uncertainties could reduce the volumetric requirements for terminal area procedures, resulting in airspace design options not available today and the ability to fit more aircraft within a given airspace volume. NextGen proposes reducing all forms of separation between aircraft as a requirement for increasing capacity, and reducing the variability in the spacing between aircraft is proposed as a needed efficiency improvement.

Current operational methods of separating aircraft rely too heavily on verbal communication between operators, such as the challenge and response communication procedures used when separating aircraft through positive control methods, and the direct coordination required between controllers of adjacent airspace sectors when aircraft are operating near or crossing airspace boundaries. The requirement for verbal communication is not only inefficient, but increases the likelihood for communication errors. Data link communication holds the promise to deliver clearance and other information to aircrews using standardized, unambiguous terminology, potentially directly into on-board automation systems without the time-consuming and uncertainty producing procedures used today.

The majority of today's air traffic procedures are based on navigation performance assumptions that don't reflect the performance achieved by the flight management systems and autopilots found in most transport category aircraft using terrestrial navigation sources or celestial navigation sources such as the Global Positioning System (GPS). Implementation of

Required Navigation Performance (RNP) procedures, which require specific navigation performance levels, has the potential to shrink required airspace volumes and eliminate conflicting and/ or shared arrival and departure resources among metroplex airports.

Automatic Dependent Surveillance automates aircraft position reporting using data link communications. Automatic Dependent Surveillance-Broadcast (ADS-B) which requires aircraft to report both their position and its accuracy to air traffic systems at five to 100 times the frequency that terminal radar systems detect it, could also contribute to reduced separation standards by reducing surveillance uncertainties. It also holds the promise to permit aircraft to receive ADS-B messages from other aircraft and execute spacing and/ or separation maneuvers based on their relative position⁸.

Demand can exceed metroplex capacity, suggesting that demand management measures may be needed if capacity cannot be increased to meet it. FAA demand management proposals generally focus on limiting operations. When demand is anticipated to exceed capacity today, air traffic managers delay or deny operations. These demand management practices result in lost capacity when demand is limited to capacity forecasts that underestimate actual capacity.

Understanding demand versus capacity imbalances is critical to maximizing system productivity today, and to ensuring the effectiveness of tactical and strategic air traffic management functions under NextGen. At present, demand management does not rely on objective measures to forecast arrival and departure capacities, but relies on estimates by air traffic facility managers based on their experience dealing with similar demand and resource situations to set target rates for current and anticipated conditions. Managers have few, if any, incentives to be optimistic in their estimates, and, in fact, have many disincentives to being aggressive in their capacity estimates. Their conservatism is another source of constraint on system productivity. The system should be operated in such a way as to continuously stress the limiting elements to ensure that capacity is not lost. Metrics and the tools to use them need to be developed that are objective, predictive, and accurate in their estimation of airport capacity.

The NextGen interaction model addresses demand versus capacity imbalance from both the strategic and tactical perspectives of air traffic management. At the strategic level, if Capacity Management functions fail to provide needed capabilities, Flow Contingency Management functions would be used to define strategies to deal with the demand versus capacity imbalances. FCM would implement collaborative air traffic management processes to ensure safety is maintained while demand is accommodated with some concurrent delay, which is not much different than how the FAA manages traffic today. At the tactical level, Trajectory Management incorporates trajectory negotiation and assignment of sequences and spacing. In today's system, departure sequencing is assigned through establishment of EDCTs at the en route center, as described earlier. For metroplexes, this can result in multiple airports being prioritized as a single source of departures and an inequitable and inefficient allocation of capacity between en route traffic and departures from all or any of the metroplex airports. Air traffic sequencing and spacing applications need to be researched, developed, and implemented in both air traffic control systems and aircraft to permit flexible, effective, and efficient traffic flows whose optimization is locally determined.

NextGen proposals for solving demand versus capacity imbalances generally focus on meeting excess demand rather than limiting it, although a portion of the Flow Contingency

⁸ These are often referred to as Airborne Separation Assistance System (ASAS) operations. More information on ADS-B applications and ASAS operations can be found at: <http://adsb.tc.faa.gov/ADS-B.htm>

Management function discusses limiting demand. While a number of the proposals discuss market-driven alternatives, none acknowledges the potential for market-driven initiatives to include alternatives that relieve demand through capacity displacement into other forms of transportation or construction of airports beyond those currently existing in metropolitan areas. This omission ignores the market-driven success of low cost carriers that have targeted underutilized metropolitan area airports, as well as the migration of business and other air travelers away from commercial carriers toward corporate and air taxi operations. Research on alternatives to existing commercial service operations at existing metroplex airports is needed to determine the potential for system productivity enhancement from non-traditional sources.

As a result of increasing business and air taxi operations, metropolitan area reliever airports are increasingly integral to metroplex resource sharing. In the NY/NJ metroplex, airspace planners consider that five area airports⁹ create significant, negative metroplex effects. Currently, each is considered a primary, commercial service airport by the FAA's National Plan of Integrated Airport Systems (NPIAS), which forecasts that in 2013 three will remain large hub passenger airports that together will enplane more than 60,000,000 passengers, that one will remain a small hub passenger airport with nearly 400 GA aircraft based there, and that the fifth, which currently handles ~200,000 aircraft movements per year and is Part 139 certified¹⁰, will be reclassified as a reliever airport.¹¹ Failing to consider the impact of shifting air transportation demographics and the changes required of air traffic and aircraft systems to support them will limit the effectiveness of plans focused primarily on commercial services. Research that focuses on business and air taxi operations will also provide an opportunity to work with the most technologically advanced aircraft in service to support system evolution that enhances capacity rather than limits demand.

Metroplex capacity limits result from real, rather than artificial, constraints to system productivity, and significant research is required to address them. Decoupling metroplex airport operations provides the greatest potential to increase system productivity. Better application of existing technologies with the potential to reduce airspace volumetric requirements would significantly alter the dependencies between metroplex airports and could significantly increase metroplex capacity. Understanding demand versus capacity imbalances is critical to responding successfully with both tactical and strategic capacity enhancing solutions. Research that considers not only commercial aviation services, but emerging and future aviation alternatives, is needed to both understand the demand and capacity issues and to craft tactical and strategic solutions to them.

Airport

The goal of the air transportation system is the movement of aircraft from one airport to another; ultimately, air transportation system productivity is realized when aircraft arrive at destination airport terminals. Individual airport productivity is measured not in terms of arrivals, but in terms of throughput, because airports are an element of the air transportation system network. Addressing en route system limitations will necessarily have implications for airports, as will addressing metroplex shared resource constraints. If en route operational practices no longer constrained system productivity and shared resource constraints were eliminated where possible, individual airports would limit system productivity. Improving system productivity would then require that constraints associated with individual airports be addressed.

⁹ LGA, JFK, EWR, TEB, and HPN

¹⁰ http://www.panynj.gov/CommutingTravel/airports/html/teb_operations.html

¹¹ NPIAS 2009-2013, Appendix A

From a productivity perspective, individual airport constraints are generally associated with an airport's physical configuration, including runways, taxiways, and gates, and with the effect that physical considerations have on surface operations. Surface operations often interact with terminal airspace operations, which further complicate their management. Surface operations are much better suited to network analysis than the air traffic system is as a whole, in part because they are generally fully constrained in three dimensions (latitude, longitude, and time) versus partially constrained in four dimensions (latitude, longitude, altitude, and time). Solutions to airport surface operations issues are often dependent on physical infrastructure changes rather than being primarily procedural or technology driven. However, procedures supported by technologies determine airport design standards, in turn limiting infrastructure options. Therefore, airport solutions must address each of these.

Runway associated constraints are typically driven by separation standards for flight operations, which are strongly influenced by the same communications, navigation, and surveillance uncertainties that drive airspace design standards and are discussed in the Metroplex section. Runway productivity is limited by the procedures used to deliver aircraft to the runway on arrival, to clear aircraft for takeoff on departure, and by the time aircraft are resident on the runway during either.

For arrival and departure operations under instrument flight rules (IFR), sequential and lateral separation requirements, expressed as radar separation standards, limit the number of aircraft that can be guided over one particular point, such as a runway threshold, in a given time. IFR wake turbulence separation standards exceed radar separation standards for all aircraft pairings other than large to large pairings, further limiting the number of aircraft that can transit a given point in a given time. Under visual flight rules (VFR) pilot acceptance of an instruction to 'maintain visual separation' as part of an air traffic control clearance transfers aircraft and wake turbulence separation responsibility from air traffic controllers to flight crews. This allows pilots to maneuver relative to other aircraft at less than IFR separation distances, potentially increasing runway productivity in visual conditions. Research is needed to understand the extent to which visual operations are more productive than IFR operations, the reasons why, and how they are conducted safely. This understanding is needed to support NextGen concepts intended to achieve visual capacities in IFR conditions. Significant research is required to develop these emerging concepts; the technologies that support them require development, as does their application. In particular, automation and human factors concerns need to be explored and addressed.

Wake vortices are produced by aircraft as a physical inevitability of generating lift. Aircraft that fly into them can lose control as wake induced air movements can overwhelm the control authority of even the most maneuverable aircraft. Therefore, aircrews are trained to avoid these invisible hazards during visual operations by applying techniques developed through trial and error that assume typified wake behaviors. Air traffic controllers are obliged to provide wake turbulence separation for IFR arrivals and prior to issuing takeoff clearances for all departures. Airports constructed with parallel runways spaced less than 2500' apart on centerline are restricted to treating the runway pair as a single runway during IFR arrivals and for departure operations involving Heavy and 757 aircraft, because of wake turbulence considerations. Runway intersections through which aircraft are airborne are similarly operationally limited by wake turbulence considerations. Wake turbulence operational considerations affect the placement of runways by airports making infrastructure investments, and have significant impacts on construction project costs.

Wake turbulence will remain a significant hazard to flight in the future, and therefore a constraint on productivity. Many NextGen concepts rely on reducing separation between aircraft, but either ignore the potential for wake encounters or dismiss it based on an assumption that the issue of wake turbulence will be solved separately. If reduced uncertainties in CNS systems permit a reduction in large to large aircraft separation from today's radar separation standards, wake turbulence could emerge as the dominant separation criterion for all operational aircraft pairings.

As a result of improved computational capabilities and the advent of sensors that can directly measure the vorticity of wakes, significant progress has been made in recent years in understanding the behavior of wakes. The FAA has instituted changes in procedures based on this improved understanding, and is in the process of defining and acquiring air traffic system capabilities to safely suspend current wake turbulence separation standards under certain weather conditions. Developing concepts that assume wake turbulence doesn't or won't exist, or which otherwise seek to increase productivity without regard to the hazard wake turbulence poses, cannot increase productivity beyond the limit that wake turbulence separation standards do or will impose. The FAA has an ongoing wake turbulence research program in place with plans to address wake turbulence imposed operational constraints as NextGen evolves. Research is needed that supports this program and its concepts for reducing wake turbulence constraints.

Taxiway constraints are primarily associated with physical space and its configuration. Taxi operations rarely follow the exact sequence or path preferences of operators due to a lack of communication and coordination of these preferences within and between operating organizations. Even with improved communication and coordination, surface traffic surveillance information is insufficient to permit management of surface traffic in accordance with the expressed preferences, and at most airports, there is not sufficient physical space to permit reordering of traffic to achieve preferences as they change.

Ideally, aircraft would be able to move from runway to gate and gate to runway using minimum distance routings that are unimpeded. Surface Management Systems (SMS) can reasonably support traffic management on the airport surface when provided accurate estimates of demand that include spatial as well as temporal information. However, uncertainties in gate pushback times, in anticipating runway in use changes, in runway exit on landing, in gate assignment, and in forecasting runway demand limit the effectiveness of SMS. Research is needed that focuses on surface movement uncertainties and seeks to reduce them in order to improve the effectiveness of SMS.

Implementation of SMS will require research that develops concepts for communication and coordination between operating organizations, and may require regulatory or policy changes that support this. SMS will need to be able to optimize surface operations within a wide range of arrival versus departure demand, and with limited options to reorder traffic already on airport movement areas. If the airport surface represents a constraint on productivity, it will be important to maintain demand at or above surface capacity in order to ensure capacity is not lost on the surface. The development of metrics focused on the effect the number of aircraft on the surface has on airport productivity is needed.

Gate management is also an area that affects airport productivity. Not all gates have the physical ability to service all aircraft types, limiting operators' gate assignment options. When aircraft arrive early, or are delayed in pushing back, gate assignment plans based on the flight schedule must change. When arrivals significantly exceed departures, the inventory of aircraft on the airport surface can rise dramatically, limiting operators' and air traffic controllers'

abilities to efficiently manage surface operations, especially at airports where surface space that can absorb such imbalances is limited. During imbalanced periods, variability in the arrival and pushback delay times creates significant challenges for gate assignment. Research that focuses on identifying the dependent and independent variables associated with gate management is needed, along with the development of gate management concepts that integrate with SMS functions to ensure that gates are not the primary constraint on airport productivity.

Deicing requirements also act as a significant constraint specific to departure operations. Deicing operations frequently increase gate to runway times beyond that planned for scheduled flight operations, making it more difficult for operators to meet schedules. Operators often have no operational control over deicing assets, introducing uncertainties in the timing of deicing services at many airports. Over the last several years the FAA has placed changing restrictions on operations during inclement winter weather which have made compliance more complex, more subject to error, more time consuming, and more costly for aircraft and airport operators. Research in the area of aircraft icing has historically resulted in more restrictive regulations associated with potential icing conditions. However, research that leads to advances in meteorological sensing and forecasting could help to narrow the focus of deicing procedures to only those conditions that are known to produce dangerous icing, which could reduce operational requirements in the presence of potential icing conditions.

Another area of concern unique to airports is the encroachment of obstacles into airports' airspace protection zones. The FAA has regulations in place that limit construction of structures that penetrate protected airspace, however, the courts have increasingly granted developers exceptions to these regulations, restricting procedure development in the impacted airspace, effectively making an already finite resource scarcer. Environmentalists have even prevented airports from cutting trees to comply with obstacle clearance requirements for runways. This has become a critical safety issue for airports in developed areas, and the Competition for the Sky Conference¹² held by the FAA in August 2008 focused on ensuring transparency and collaboration in airspace management, as well as understanding the need for preservation and protection of airspace for future use. The same technologies and procedures that could permit decoupling of shared resources in metroplex environments through more resolute flight procedure compliance may also provide an opportunity to reduce competition for airspace by reducing airspace volumetric requirements.

Gate-to-Cruise Issues and Constraints Summary

The issues and constraints imposed on gate-to-cruise departure operations have been presented within the hierarchy of en route, metroplex, and individual airports, with approaches to increase departure capacity within each identified. The discussions are in rank order, from greatest to least, of the constraint each of these elements presently imposes on system productivity. This ordering is consistent with the order in which the constraints must be addressed in order to achieve any significant benefit in terms of departure productivity.

The en route constraints are real, in that they truly affect operations, but are artificial in that they are largely unnecessary given the potential productivity of en route airspace available today based on existing technologies and procedures.

Metroplex constraints are mostly real, in that most cannot currently be addressed using technologies and procedures available today. Wherever possible, solutions that provide for

¹² See http://www.faa.gov/news/conferences_events/competition_sky_2008/ for conference related information

independence between metroplex operations should be implemented. Where this is not possible, solutions that maximize the productivity of shared resources should be implemented.

Airports are where system productivity is realized; they have real, unique operational constraints, which are affected by, and affect, their physical infrastructure. If the artificial constraint imposed by en route airspace management practices is removed, and metroplex operations are made independent wherever possible, airports will constrain departure productivity. Protection of terminal area airspace is critical to supporting future operational concepts. Solutions that improve surface operations and gate management are needed to increase airport, and thereby, departure productivity.

Many of the issues and constraints identified in this section have underlying organizational or technical challenges that span multiple operational phases. These crosscutting aspects will be addressed in the following sections.

ORGANIZATIONAL AND TECHNICAL CHALLENGES IN GATE-TO-CRUISE OPERATIONS

This section provides a crosscutting perspective on the organizational and technical challenges associated with gate-to-cruise operations. For many, though certainly not all, of the issues and constraints identified in this paper, technologies and capabilities exist today that would enable greater productivity of the air transportation system; the others will require significant research and development to address them.

Organizational Challenges

In the air transportation system, achieving change represents a significant leadership challenge. The many different stakeholders in the air transportation system all have an interest in the productivity of the system, but each has different and often competing business models motivating their use of the system. Resistance to change is an organizational challenge independent of operational phase and seemingly impervious to evidence of success or failure. Within nearly all organizations, cultural influences result in organizational behavior that serves to preserve the status quo. Prior success can reduce the motivation to seek opportunities for improvement, and even blind organizations to them.

To change gate-to-cruise operations, numerous organizations, including airline operations, maintenance, dispatch, and ramp control, as well as air traffic ground, tower, and en route controllers and managers would have to participate in developing a new process for effectively and efficiently moving aircraft from gate-to-cruise. It may be necessary to educate stakeholders on the concept that the least productive element of the system limits its overall productivity and that committing resources to increasing the capacity of unconstrained elements will not increase system productivity. In many cases, a clear and convincing benefit versus cost argument associated with a change will have to be shown to begin to address system constraints.

Even when an appropriate change is identified and agreed to, and all parties are motivated to adopt new behaviors, change is difficult. It requires leadership, hard work, coordination, an effective reward system that supports lasting change, and effective feedback mechanisms to monitor actual versus desired outcomes, and to identify emerging constraints, issues, and potential improvements. Organizational change is especially challenging, as it requires new behaviors and perspectives at multiple levels simultaneously, from the line worker to the executive management team.

Policies also pose a significant challenge to change, as policies are established specifically to maintain safety, and to guide operational decision making. Air traffic system regulatory policies, in particular, limit operator decisions and operational options. Some of these policies institutionalize constraints to such a degree that they aren't recognized as constraints but become operational norms that go unquestioned in spite of their negative effects on productivity.

For example, the FAA's response when operational demand exceeds capacity today is nearly always to reduce traffic demand rather than to increase capacity. This policy underlies the en route constraint on system productivity today.

The FAA's Air Traffic Control System Command Center manages the flow of air traffic within the contiguous United States, and takes actions to limit traffic demand when it exceeds capacity through collaborative decision making that involves both aircraft operators (primarily airlines) and air traffic managers. The ATCSCC frequently restricts traffic demand by implementing ground delay programs which hold aircraft at the departure airport if the arrival airport or the routes to it are forecast to be beyond capacity. Ground delay programs, designed and originally used only for severe weather disruptions, are increasingly used in response to anticipated congestion in the system.¹³ A number of other traffic management initiatives exist that the ATCSCC could use to manage traffic flow; however, the most frequently used initiatives reduce traffic demand rather than increase capacity. These initiatives are planned and executed through centralized air traffic management functions in anticipation of capacity limited conditions rather than in response to them, making it impossible to recover lost capacity when actual conditions aren't as limiting as anticipated.

The current practice of centralizing planning and control of traffic demand is not scalable or flexible. The FAA's predilection for centralized, inflexible, demand management over capacity enhancement is evidenced by its adoption of final rules imposing regulatory demand management programs for scheduled and unscheduled operations at the three NY/NJ large hub airports, Reagan National (DCA) airport, and Chicago O'Hare (ORD) airport.¹⁴ Policies, procedures, and practices that are distributed and which localize solutions to the constraints have the greatest potential to provide scalable, flexible capacity more able to respond to demand than today's system. To maximize system throughput, policies and practices must change to ensure demand on the most constrained elements of the system consistently meets or exceeds their capacity. Tools are needed to ensure that the inventory of aircraft stressing system bottlenecks actually require routing through them, and to ensure these elements continuously operate at their maximum capacity.

Technical Challenges

This section identifies crosscutting challenges associated with issues and constraints that require technology-focused solutions. It considers departures as only one element of the complete operational context, and as suggested earlier, solutions to the constraints affecting metroplex departure operations should be approached from a system perspective. Wherever possible, shared resource constraints should be eliminated.

The greatest technical challenge in addressing gate-to-cruise constraints is in translating the understanding of the constraints into capacity that is reliably available under as many

¹³ Terminal Chaos, George L. Donohue, Shaver, Edwards, 2008, pg. 20

¹⁴ See <http://www.fly.faa.gov/ecvrs/> for information on unscheduled operations requirements at these airports. See Federal Register Vol. 71, No. 167 page 51382, Vol. 73, No 198, pages 60544 and 60574, and Vol. 73, No. 211 page 64515 for final rule information.

conditions as possible. A crosscutting aspect of doing so involves implementing ground and airborne technologies that permit the full capabilities of each to be realized in all operational regimes. Automation concepts for aircraft and air traffic systems that have appropriate safety checks on each other and balance human and automation functional allocation are needed. Active participation of aircraft within the air traffic system will be required to accomplish this, and consideration of the best ways to integrate aircraft capabilities into the air traffic system is required to support their participation. Changing air traffic control communications protocols to include data link communications is necessary to address the constraints imposed by the use of voice communications. A great deal of work is needed on the technical, human factors, and procedural aspects of making such changes.

Eliminating shared resource constraints is not equivalent to eliminating all sharing of resources, and is not suggested here. Airspace, communications systems, air traffic controllers and managers, and various other NAS elements will always be shared, and will always represent a potential constraint within the system. Resource sharing, when constrained, always results in certain participants ‘losing’ in the sense that they do not achieve their preferred performance even though they may achieve acceptable performance. Given this, research is needed to understand what constraints are in fact insurmountable, and to what extent, and to determine how the constrained resources can be equitably allocated for the benefit of all system users. NextGen concepts for trajectory-based operations identify the need to develop communications methods for use between air traffic system operators and users that ensure a thorough and accurate understanding of flight operations preferences, which will require technology-focused solutions.

Once shared resource issues have been addressed, constraints and issues associated with individual airports can be addressed, such as the scheduling and sequencing of aircraft in and out of airports. Significant work associated with airport surface operations remains to be done to ensure safe and efficient high volume operations. Trajectory based operations in both the surface and airborne environments will require the development and testing of computational, control, and information display concepts. Models and algorithms for fast-time and piloted simulations are required that consider mixed traffic and the various airborne capabilities represented, that schedule traffic in the most efficient manner, and that sequence traffic to maintain minimum, safe separation, optimized to accommodate wake turbulence separation standards.

While this paper primarily focuses on gate-to-cruise metroplex departure operations, these technical challenges apply beyond this operational focus. Specific research and development tasks aimed at addressing these challenges in other domains will be defined within the research road maps being developed as part of this effort.

CONCLUSIONS

This paper presents the idea that the current air traffic system is artificially limited in its productivity by centralized, systemic constraints. It suggests that removing these constraints will distribute the constraints to localized areas within the system. While this may appear at first to multiply the constraints, or to simply shift them around, as the constraints are distributed, they will become easier to identify and characterize, and their solutions will become more obvious, more readily achievable, and more optimal. Distributed solutions will also be more scalable, a critical shortcoming of the current centrally managed system.

Based on input received from multiple stakeholders and the review of research activities related to the capacity and efficiency of the U.S. air traffic system, the following conclusions can

be drawn regarding gate-to-cruise metroplex departure operations. These conclusions have implications for other air traffic system domains as well.

The safe and efficient movement of aircraft from one airport to another is the ultimate goal of the air transportation system. The productivity of the system designed to support these movements is limited by the most constrained element within the system through which aircraft must pass. Solutions to increase system productivity must be focused on the productivity-limiting elements of the system.

Today's en route airspace environment is unnecessarily characterized by a limited number of fixed routes to which air traffic controllers restrict aircraft trajectories. En route airspace represents the ultimate shared resource within the air traffic system, with the greatest potential for productivity. Due to the inefficient use of en route airspace, however, it is a dominant factor in generating delays for departure traffic.

Applied research and development should focus on increasing metroplex capacity by eliminating shared resource constraints wherever possible, rather than approaching the issues and constraints associated with metroplex departure operations with the intent of improving upon current practices. Only after shared resource constraints are shown to be impossible to eliminate should research and development focus on the optimization of the use of shared resources. Research is required to better understand metroplex constraints, to determine minimum total loss concepts associated with shared resources, and to develop and implement solutions that increase the productivity of shared resources within metroplexes through organizational changes and the implementation of aircraft and air traffic system technologies.

APPENDIX A: LIST OF ACRONYMS

| Acronym | Expansion |
|---------|--|
| 4DT | Four Dimensional Trajectory |
| ADS-B | Automatic Dependent Surveillance- Broadcast |
| AGL | Above Ground Level |
| AIAA | American Institute of Aeronautics & Astronautics |
| ANSP | Air Navigation Services Provider |
| AOC | Airline Operations Center |
| APU | Auxiliary Power Unit |
| ARC | Aviation Rulemaking Committee |
| ARMT | Airport Resource Management Tool |
| ARTCC | Air Route Traffic Control Center |
| ASAS | Airborne Separation Assistance Systems |
| ASDE-X | Advanced Surface Detection Equipment- Ten |
| ASPM | Aviation System Performance Metric |
| ATC | Air Traffic Control |
| ATCSCC | Air Traffic Control System Command Center |
| ATIO | Aviation Technology, integration, and Operations |
| ATL | Atlanta Hartsfield International Airport |
| C-ATM | Collaborative Air Traffic Management |
| CLOU | Cooperative Local Resource Planner |
| CM | Configuration Management |
| CNS | Communication, Navigation, and Surveillance |
| ConOps | Concept of Operations |
| CSPO | Closely-Spaced Parallel Operations |
| CTA | Controlled Time of Arrival |
| DCA | Ronald Reagan Washington National Airport |
| DDTC | Digital Delivery of Taxi Clearance |
| DFW | Dallas-Fort Worth International Airport |
| DSP | Departure Spacing Program |
| DST | Decision Support Tool |
| EDCT | Expect Departure Clearance Time |
| EDP | Expedite Departure Procedure |
| EPR | Engine Pressure Ratio |
| ETOPS | Extended-range Twin-engine Operational Performance Standards |
| EWR | Newark International Airport |
| FAA | Federal Aviation Administration |
| FAM | Federal Air Marshall |
| FCM | Flow Contingency Management |
| GPS | Global Positioning System |
| HPN | Westchester County International Airport |
| IFR | Instrument Flight Rules |
| IWP | Integrated Work Plan |
| JFK | John F. Kennedy International Airport |
| JPDO | Joint Planning and Development Office |

| Acronym | Expansion |
|----------------|---|
| LGA | La Guardia International Airport |
| MDW | Chicago Midway Airport |
| NAS | National Airspace System |
| NextGen | Next Generation Air Transportation System |
| NOTAMS | Notices to Airmen |
| NPIAS | National Plan of Integrated Airport Systems |
| NPRM | Notice of Proposed Rulemaking |
| NRP | National Route Program |
| O&D | Origination and Destination |
| ORD | O'Hare International Airport |
| PDC | Pre-Departure Clearance |
| R&D | Research and Development |
| RAPT | Route Availability Planning Tool |
| RIPS | Runway Incursion Prevention System |
| RNAV | Area Navigation |
| RNP | Required Navigation Performance |
| RWY | Runway |
| SID | Standard Instrument Departure |
| SM | Separation Management |
| SMS | Surface Management System |
| SOAR | Surface Operation Automation Research |
| STAR | Standard Arrival Procedure |
| TBO | Trajectory Based Operations |
| TCA | Terminal Control Area |
| TCAS | Traffic Collision Avoidance System |
| TEB | Teterboro International Airport |
| TFM | Traffic Flow Management |
| TM | Trajectory Management |
| TMA | Traffic Management Advisor |
| TMC | Traffic Management Coordinator |
| TMU | Traffic Management Unit |
| ToC | Top of Climb |
| ToD | Top of Descent |
| TRACON | Terminal Radar Control Center |
| V ₁ | Velocity- Abort Decision |
| V ₂ | Velocity- Takeoff Safety Speed |
| VFR | Visual Flight Rules |
| V _R | Velocity- Rotate |

APPENDIX B: ISSUES AND CONSTRAINTS LISTING

The following lists the issues and constraints identified by the aviation stakeholders consulted as part of the work discussed in this paper. The classification and categorization of this information was completed by the authors.

En route Airspace Constraints

- En route integration of departure operations
- Segmented airspace from ToD to ground and ground to ToC
- Airspace sectorization
 - Design independent from operational configuration
 - Coordination requirements
- Failure to coordinate between air and ground
- Inconsistent spacing
- Shared resources
 - Arrival routes and fixes
 - Departure routes and fixes
 - Operations conducted to fill gaps in overhead stream, but gaps too few
 - Always a winner and a loser- manifested temporally
- Conflicting resources
 - Routes
 - Resulting excessive path lengths

Metroplex constraints

- Airspace
 - Flow integration priorities (airport vs. airport, arrival vs. departure)
 - En route integration of departure operations
 - Arrival merging and spacing
 - Segmentation of controller responsibilities
 - Multiple, repetitive interaction requirements
 - Separation standards based on accumulation of uncertainties, including controller disincentives to maximizing efficiency
 - Failure to maximize use of RNP
 - Failure to coordinate between airports
 - Strategic
 - Tactical
 - Failure to coordinate between air and ground
 - Inconsistent spacing
 - Shared resources
 - Arrival routes and fixes
 - Departure routes and fixes
 - Operations conducted to fill gaps in overhead stream, but gaps too few
 - Always a winner and a loser- manifested temporally
 - Conflicting resources
 - Routes
 - Resulting excessive path lengths
 - Threats to airspace from obstructions
- Relative geometries

- Distant airport metroplex effects
- Intermodal
 - Metroplex service to same destination from multiple local airports
 - Inability to move efficiently between airports in metroplex

Airport constraints

- Runways
 - Occupancy times
 - Demand forecasting
 - Runway in use decision making
 - Local effects
 - Systemic effects
 - Relative configuration/ Wake turbulence separation standards
 - Vertical standards are for level flight only
 - Standards limit ability to bring airplanes together for multiple CSPO
 - Closely-spaced parallel runways
 - Position and timing inaccuracies
- Taxi
 - Push back event uncertainty
 - EDCT sequencing and resorting
 - Impeded taxi
 - RWY in use changes
 - Clearance changes
 - Space for sorting
 - Space for off-gate aircraft
- Gates
 - Physical size limits aircraft usage options
 - Physical location requires ground controller interaction to push back
 - Utilization
 - Turn times
- Deicing operations
 - Deicing holdover times
 - Weather reporting
- Infrastructure
 - Time to change
 - Airport design standards

Organizational constraints

- Ground hold programs
- System works well at extremes, but in middling areas competitive elements destroy synergies
- Working too many problems without solving any
- Unwillingness to recognize need to change
- Discounting of requirement to serve passengers
- No entity is responsible to passengers for delay
- Lack of commitment to solving problems
- Lack of trust among stakeholders
- Unwillingness to change
- Inertia from having done it a given way before

- Competition between operators at airport/ within metroplex
- Environmental
 - Pollutant production
 - Interrupted taxi operations
 - Noise production
 - Variability in procedures
- O&D passenger limits
- Scheduling practices
 - VFR vs. IFR
 - Access
 - Competition
 - Excess scheduling (Airport & Metroplex)
 - Banking
 - Ground hold AOC preferences
- Landing fee policies
- Operator gaming of collaborative system
- Safety requirements
 - nth degree requirements
 - Automation given no credit for recourse availability
 - No credit given for failure detection
 - Including human
- Lack of commitment to solving problems
- Investment decision making is too slow, too hard to prove business case
- Lack of implementation of existing technologies
- Perimeter rules
- Call & response communications
- Permissive exception to policy for airport design standards
- Advertise capabilities without consideration of interdependencies
 - FAA Benchmark capacities not dependent on configuration

Technology constraints

- Airplane as target rather than participant
- Mismatch between aircraft and ground system capabilities
- Designs not tailored to nor optimized for human operator
- Systems don't offer solutions, and only identify problems in limited situations
- Indirect network delivery of PDC information
- Voice communication
- Clearance interpretation
 - Path depiction
- Operational uncertainties
- Need to have soft-shoulders for RNP
- Solutions not integrated
- Separate consideration of arrivals and departures
- System is inflexible, unable to absorb disruption
- Technology capabilities underutilized or not utilized
- Lack of data to support operations
- Lack of metrics to recognize constraints or support optimization
- Conflict detection and resolution below 1000' AGL where TCAS leaves off

- Surveillance accuracy
- Surveillance latency
- Lack of surveillance fusion
- Lack of conformance monitoring which would enable delegation
- Lack of time-based operations

Uncontrollable constraints

- Weather
- Military and other exigent missions
- Operator preferences
 - Routing
 - Equipage
- Human behavior

APPENDIX C: PUSHBACK-TO-CRUISE TASK LIST

This task list is an attempt to capture major issues to be considered when aircraft move from Pre-departure to pushback and on to cruise altitude. Although this list is not comprehensive, it was useful in guiding discussions with stakeholders in the development of this paper.

Pre-departure

- Airline Operational Control (AOC) considerations
 - Aircraft routing
 - Aircraft inspection schedule
 - Aircraft modification schedule
 - Aircraft configuration
 - Passenger movement
 - International travelers
 - Revenue management
 - Cargo movement
 - National Flow Control
- Maintenance considerations
 - Aircraft dispatch issues
 - Deferred maintenance
 - Aircraft servicing
 - Aircraft repair
 - ETOPS operations
- Dispatch considerations
 - Flight planning
 - Notices to Airmen (NOTAMS)
 - Proposed route of flight
 - Flight crew qualifications.
 - Federal Aviation regulations
 - Runway data
 - Runway in use
 - Runway conditions
 - Flap setting
 - Braking action
 - Visibility
 - Weight and balance
 - Runway in use
 - First segment climb
 - Second segment climb
 - Special engine out procedure
 - Restricted airspace
 - Departure weather
 - En Route weather
 - Destination weather
 - Volcanic activity
 - En Route depressurization
 - Oceanic track issues

- ETOPS operations
 - ETOPS Alternate Weather
- Re-dispatch
- Aircraft maintenance dispatch issues
- Winds
- Icing
- Aircraft weight; number of passengers, cargo, fuel requirements
- Mountainous terrain decompression route
- Filing of flight plan
- ATC coordinators
 - Airspace and runway usage
 - Ground delay programs
 - Collaborative basis with their Federal Aviation Authority (FAA) counter parts.
 - National Route Program (NRP)
 - ATC tactical re-routes
 - National flow control
- Station considerations
 - Gate assignments
 - Gate coordination with Cargo, Maintenance, Passengers
 - Passengers
 - Seat assignments
 - Baggage
 - FAM, LEO, FAA, Jump seat
 - Loading
 - Cargo
 - Mail
 - Hazmat
 - Strollers & Gate check items
 - Weather
 - De-icing
 - Water
 - Fuel
 - Cleaning
 - Lavatory
 - Pushback
 - Pushback coordination with other airlines
 - Pushback coordination with ATC
 - Estimated Departure Clearance Time (EDCT)
- Aircraft preflight – Flight Crew considerations
 - Aircraft inspection
 - Deicing
 - Type of Deicing Fluid used
 - Maintenance Release
 - Deferred maintenance
 - Dispatch modification
 - Clearance delivery
 - Weight and balance
 - Runway data

- Pre Departure Clearance (PDC)
 - Estimated Departure Clearance Time (EDCT)
 - Gate usage
- Pre-departure brief
 - Runway
 - Abort procedures
 - Engine failure
 - Wind shear
 - Weather
 - Terrain
 - Special engine out procedures
- Check List
- Digital Delivery of Taxi Clearance (DDTC)
- Metroplex Pre-departure issues
 - Runway configuration
 - Taxiway configuration
 - Wind
 - Visibility
 - Departure procedures in use
 - Arrivals in use
- Push back- Flight Crew considerations
 - Push back request
 - First departure fix
 - Expected runway
 - Metroplex coordination
 - Estimated Departure Clearance Time (EDCT)
 - Push back clearance – instructions
 - Push back coordination (other airlines)
 - Push back sequence
 - Ramp clearance
 - Ramp vehicle clearance
 - Emergency vehicles
 - Transponder
 - Multilateration
 - Check list
 - Push Back
 - Engine start
 - Anti-Ice
 - Auxiliary Power Unit (APU) usage
 - Maintenance release
 - Salute – release from guidance
- Push back issues – Ramp Tower considerations
 - Coordination with ATC Ground Control
 - Coordination with ATC (EDCT)
 - Coordination with other airlines
 - Coordinating inbound and outbound traffic

Taxi

- Ramp taxi issues - Flight Crew considerations
 - Weather
 - Rain
 - Snow
 - Visibility
 - Call for ramp taxi clearance
 - Ramp taxi instructions
 - Traffic to follow
 - Power level used to start taxi
 - Flap setting
 - Estimated Departure Clearance Time (EDCT)
 - Hold Short Instructions
- Ground taxi issues - Flight Crew and ATC considerations
 - Call for ground control taxi clearance
 - Taxi sequence
 - Snow
 - Visibility
 - Departure fix
 - Aircraft weight
 - Taxi speed
 - Distance in trail
 - Holding instructions (Long delay)
 - Hold short instructions
 - Deicing
 - Deicing pad procedures
 - Deicing pad recycling issues
- Ground taxi issues - ATC considerations
 - Coordinate with ATC tower
 - Coordinate EDCT
 - Coordination with airlines

Takeoff

- Takeoff - Flight Crew considerations
 - Checklist
 - Final weights
 - Engine power settings
 - Aircraft trim settings
 - Special Engine out procedures
 - Estimated Departure Clearance Time (EDCT)
 - Takeoff sequence
 - Aircraft category
 - Wake turbulence
 - Visibility
 - Takeoff alternate
 - Wind
 - Tailwind limit

Crosswind limits

- Altimeter setting
- Position and hold - Flight Crew issues
 - Transponder
 - Radios set
 - Wake interval
 - Visibility
 - Wind
 - Lights
 - TCAS
 - Traffic
 - Landing
 - Crossing
 - Autothrottles
- Takeoff - ATC considerations
 - Coordinate EDCTs
 - Coordinate with National flow Control
 - Coordinate arriving and departing aircraft
 - Coordinate with ATC Arrivals
 - Coordinate with ATC Departure
 - Coordinate with other Metroplex airports
 - Position and hold
 - Aircraft on approach
 - Aircraft transiting Terminal Control Area (TCA)
 - Aircraft category
 - Wake turbulence
 - Visibility
 - Wind
 - Tailwind limit
 - Crosswind limits
 - Altimeter setting
- Takeoff - Flight Crew and ATC considerations
 - Traffic
 - Wake interval
 - Visibility
 - Wind
 - Lights
 - Brakes
 - Power
 - Takeoff power point
 - Power settings
 - Engine Pressure Ratio (EPR), N_1 , Oil, Vibrations.....
 - Abort
 - Engine out
 - V_1 , V_R , V_2
 - Gear up
 - Flight Mode Annunciator - Navigation
 - Flaps up

- After takeoff checklist

Departure

- Departure aircraft perspective
 - Engines
 - Traffic
 - Turbulence
 - Flight Mode Annunciator
 - Altitude
 - Emergency situations
 - Radios
- Departure ATC perspective (10,000 feet and below)
 - Aircraft altitude
 - Aircraft ground track
 - Other traffic
 - Coordination with Air Route Traffic Control Center (ARTCC)
 - Coordination with other Terminal Radar Approach Control (TRACON) controllers
 - Coordination with Tower
 - Aircraft speed
 - Emergency situations
 - Special aircraft
 - Airspace constraints
 - Weather
 - Letters of agreement
 - Special use airspace
 - Radar
 - Radios
- Climb out (10,000 feet to Flight Level 230)
 - Terminal Radar Approach Control (TRACON)
 - Coordination with Air Route Traffic Control Center (ARTCC)
 - Coordination with other TRACON controllers
 - Aircraft altitude
 - Aircraft ground track
 - Other traffic
 - Aircraft speed
 - Emergency situations
 - Special aircraft
 - Airspace constraints
 - Weather
 - Letters of agreement
 - Special use airspace
 - Transition Level
 - Radar
 - Radios

En Route

- En Route ATC
 - Coordination with other ARTCCs

- Coordination with various TRACON controllers
- Coordination with National Command Center
- Aircraft altitude
- Aircraft ground track
- Other traffic
- Aircraft speed
- Emergency situations
- Special aircraft
- Airspace constraints
 - Weather
 - Letters of agreement
 - Special use airspace
- Transition Level
- Radar
- Radios

APPENDIX D: NEXTGEN PLANNING AND GATE-TO-CRUISE RESEARCH

This appendix provides information on NextGen concepts and plans developed by the JPDO that relate to Gate-to-Cruise operations, on research and development activities described in JPDO, FAA, and NASA documents, and on selected previous and ongoing research by NASA and others that was reviewed in the development of this paper.

NextGen Vision for Gate-to-Cruise Operations

Future concepts of operation for the air transportation system were considered to determine their potential to change the air traffic environment and the constraints associated with gate-to-cruise operations, as well as to identify where NASA research might affect them. The Joint Planning and Development Office (JPDO), a multi-agency government-industry initiative, is charged with developing the concepts, architectures, road maps, and implementation plans for transforming the current national Air Transportation System into the Next Generation Air Transportation System. It was primarily from JPDO products that future gate-to-cruise operations were characterized.

The JPDO NextGen Concept of Operations¹⁵ (ConOps) focuses on transforming the current air transportation system into a collaborative air traffic management (C-ATM) framework with multiple horizons associated with strategic and tactical air traffic management functions. Trajectory-based operations (TBO), described in four-dimensions for all phases of aircraft movement, including surface, terminal, and en route operations, will become the dominant methodology for commercial and advanced non-commercial traffic. The NextGen ConOps describes a number of complimentary air traffic management system-based and aircraft-based capabilities designed to provide safe, efficient, high-volume operations in high-demand environments.

The four main functions associated with NextGen trajectory-based operations are Capacity Management, Flow Contingency Management, Trajectory Management, and Separation Management. Capacity Management (CM) is used to match airspace design and configuration and other NAS resources with anticipated demand. Flow Contingency Management (FCM) is used to implement strategic initiatives to respond to imbalances in CM planning as a result of severe weather or other temporary airspace restrictions, minimizing their impact on other operations. Trajectory Management (TM) adjusts individual aircraft trajectories for safety and efficiency. Separation Management (SM) tactically resolves conflicts between aircraft and provides separation from other aircraft, terrain, weather, and other hazards. The time frame for CM is on the order of years, while the time frame for SM is on the order of seconds to minutes, FCM has a time frame from days to months, while TM has a time frame on the order of a given flight operation's duration, including planning and execution.

The NextGen ConOps envisions TM and SM as integral to planning and executing four dimensional trajectories (4DT). A 4DT is a precise, Earth-referenced description of an aircraft's intended path in space and time, containing altitude and controlled times of arrival (CTAs) at waypoints to describe the path. The NextGen ConOps describes TM and SM functions as capabilities existing in both air traffic management systems and on-board aircraft, permitting either element to determine and manage trajectories and separation using procedures consistent with aircraft capabilities.

¹⁵ Joint Planning and Development Office Concept of Operations for the Next Generation Air Transportation System version 2.0, 13 June 2007, available at: http://www.jpdo.gov/library/NextGen_v2.0.pdf

For departure operations, the TM and SM functions, and the use of 4DTs extends to surface operations as well as to takeoff and climb portions of a departure. Under NextGen, as the density and complexity of operations increase, these elements of C-ATM become more critical to conducting safe, efficient high and super density operations.

Surface TM functions are intended to support flexible surface operations, expedite surface movements, reduce queues, and support safe crossing of active runways using advanced surface management systems and decision support tools that optimize the use of runways, taxiways, and gates in all operating conditions. According to the JPDO Integrated Work Plan¹⁶ (IWP) a detailed operational concept for surface movement is not anticipated until 2011.

The use of CTAs in 4DTs is not well described for surface operations in either the NextGen ConOps or the IWP. The lowest level of trajectory negotiation, in the form of decision support tools that facilitate negotiation of CTAs between controllers and flight operators in support of time based metering into terminal areas is not expected to be available until at least 2013, and is not yet fully described. The use of CTAs for departure operations is not identified in the IWP.

Overall, the NextGen concepts associated with departure operations must generally be augured from their association with arrival operations. This lack of focus on departure operations as a distinct area of NextGen planning is inconsistent with the prevalence of departure constraints within the system today, and greater focus on departure issues is needed.

RESEARCH AND DEVELOPMENT PLANS

This section summarizes pertinent research and development plans described in JPDO, FAA, and NASA documents.

JPDO Integrated Work Plan:¹⁷

The Next Generation Air Transportation System (NextGen) represents a comprehensive transformation and evolution of our nation's air transportation infrastructure, with the JPDO Integrated Work Plan specifying required infrastructure development, integration, and, operation. The NextGen capacity goal is to effectively handle more than double the current traffic demand by 2025. This cannot be accomplished without a fundamental shift to trajectory and performance-based operations with full situational awareness and integration of weather, safety, security, and environmental information. NextGen's vision of Trajectory Based Operations (TBO) includes the integrated management of aircraft movement on the surface and during all phases of flight, using precise four-dimensional trajectories (4DTs) in the most efficient, safe, secure, and environmentally responsible manner possible. Trajectory Management operational improvements describe the evolution from today's safe, yet inefficient and capacity-limited system. In today's system, controllers guide aircraft along rigidly defined routes, over inefficient and constrained voice communication systems, using a multitude of loosely integrated information systems with imprecise position information. Trajectory Management operational improvements describe: the improvements in the surface, arrival/ departure, and en route domains; the increasing levels of Decision Support Tools (DST) introduced for ANSP and aircraft support; the changing roles of humans and automation; and the eventual transformation

¹⁶ Joint Planning and Development Office Next Generation Air Transportation System Integrated Work Plan version 1.0, 30 September 2008, available at: <http://www.jpdo.gov/iwp.asp>

¹⁷ Available at: <http://www.jpdo.gov/iwp.asp>

to highly efficient and flexible operations using advanced and integrated DSTs, and CNS systems.

Some trajectory-based and performance-based concepts require further research and development (R&D) to guide the overall NextGen effort. The more challenging areas include: the integration of safety-critical digital exchange of information, such as 4DT and flight clearances into the operational processes and systems used for flight management and control; algorithms for dynamic, real-time trajectory management, incorporating conflict management, flow optimization, and multiple user preferences; the allocation of roles and responsibilities between automation and humans, as well as the allocation between controllers and flight crews; performance-based separation standards including wake turbulence factors; automation-assisted en route flight plan negotiation that accommodates changing conditions, such as weather and non-routine operations; aircraft equipment, such as displays and alerting systems, that support independent parallel or converging runway approach procedures; and an integrated simulation and modeling environment for the National Airspace System (NAS) that incorporates elements, such as airport demand and capacity, airspace allocation, aircraft performance capabilities, as well as environmental and safety performance management.

FAA Flight Plan (2009 – 2013):¹⁸

The Greater Capacity section of the FAA's Flight Plan commits the FAA to the goal of working with local governments and airspace users to provide increased capacity and better operational performance in the United States airspace system that reduces congestion and meets projected demand in an environmentally sound manner. The overall objectives for this goal are presented below, along with the strategies and initiatives required to meet these objectives.

- Objectives:
 - 1. Increase airport capacity to meet projected demand and reduce congestion.
 - 2. Increase reliability and on-time performance of scheduled carriers.
 - 3. Address environmental issues associated with capacity.
- Strategy: Meet the new and growing demands for air transportation services through 2025 through the interagency effort of the JPDO.
 - Initiatives:
 - Work with interagency groups to achieve an agreed upon plan for integrated weather activities
 - Expand FAA's NextGen Implementation Plan to incorporate critical path decisions and milestones necessary to accomplish the Mid-term commitments
 - By FY 2010, operationally implement ADS-B for air traffic services at selected sites and continue development of surface conflict detection in the cockpit and near-term Air-to-Air applications
- Strategy: Improve airspace access and modify separation standards to increase capacity and allow more efficient use of congested airspace.
 - Initiatives:
 - Redesign terminal airspace and change procedures to increase capacity.
 - Evaluate and expand the use of Converging Runway Display Aids at airports with intersecting runways.
 - Implement the road map for performance-based navigation by the continued development and implementation of Area Navigation (RNAV) routes, SIDS, and

¹⁸ Available at: http://www.faa.gov/about/plans_reports/

- STARS. In FY 2009 -2013, publish 50 RNAV SIDs and STARs and 12 RNAV routes annually.
- Facilitate and expedite the development and approval of RNAV or RNP procedures developed by both the public and private sector.
- Conduct research to improve safety and increase throughput using wake turbulence monitoring, operational procedures, and controller tools.
- Evaluate the use of the “proximity event” classification for wake turbulence separation on final approach.
- Strategy: Improve bad weather departure and landing capacity with new technologies and procedures.
 - Initiatives:
 - Develop flexible arrival/departure corridors.
 - Identify and implement procedures and technology to improve the dissemination of weather information to pilots and controllers.
- Strategy: Increase aviation capacity and reduce congestion in the 7 Metro areas and corridors that most affect total system delay. For FY 2009, those areas are San Francisco, Los Angeles, Las Vegas, Chicago, Charlotte, New York, and Philadelphia.
 - Initiatives:
 - As identified with industry stakeholders, continue implementing operational initiatives at the New York Metropolitan airports.
 - Increase airport capacity through the use of Traffic Management Advisor (TMA).
 - Implement TMA/Time-based Metering at New York Kennedy and LaGuardia Airports.
 - Redesign the airspace of the 7 Metro areas including the continued implementation of the NY/NJ Airspace Redesign Project.
- Strategy: Promote the use of automated systems that provide more accurate and timely information for all system users.
- Strategy: Restructure airspace to ensure efficient traffic flow between oceanic and domestic airspace.
 - Initiatives:
 - Use new equipment and technology to reduce en route congestion.
 - Implement high-altitude airspace redesign to reduce congestion.

NASA Airspace System Program Project Plans:

Specific technical goals for Airspace Project¹⁹ include: increasing capacity through dynamic allocation of airspace structure and controller resources; and effectively allocating demand through departure time management, route modification, adaptive speed control, etc., in the presence of uncertainties such as wind prediction, dynamic convective weather, aircraft performance, and crew/airline procedures and preferences.

From the Airportal Project,²⁰ specific technical goals include: developing trajectory-based automation technologies to increase the safety and efficiency of surface operations and minimize runway incursions in all weather conditions; enabling reductions in arrival and departure separation standards while balancing arrival, departure, and surface capacity resources at a single airport; and enabling the use of dynamic NextGen resources by addressing the following challenges in the air portal environment: (1) creation of seamless traffic flow by

¹⁹ The NGATS Airspace Project Plan is available at: http://www.aeronautics.nasa.gov/nra_pdf/airspace_project_c1.pdf

²⁰ The NGATS Airportal Project Plan is available at: http://www.aeronautics.nasa.gov/nra_pdf/airportal_project_c1.pdf

integration of dynamic operator roles, decision aids, sensor information, air portal and terminal area constraints, real-time weather information, and regional/metroplex operations; and (2) identification and understanding of new roles, responsibilities and authority required between humans and automation.

The NGATS-ATM Airportal Project develops and validates algorithms, concepts, and technologies to increase throughput of the runway complex and achieve high efficiency in the use of air portal resources such as gates, taxiways, runways, and final approach airspace. NASA research in this project will lead to development of solutions that safely integrate surface and terminal area air traffic optimization tools and systems with 4D trajectory operations for both arrivals and departures. Ultimately, the roles and responsibilities of humans and automation influence in the ATM will be addressed by both projects.

PREVIOUS AND ONGOING RESEARCH EFFORTS

This section provides a summary of selected research reports, papers, and presentations that were reviewed in the development of this paper. The material includes research that addresses the management of departure traffic, the integration of both arrival and departure traffic management, and the safe and efficient management of surface operations. The research described in this section represents only a small portion of research conducted with implications for metroplex departure operations and NextGen concepts.

NASA and NASA-Sponsored Research

NASA has performed research to improve the safety and efficiency of surface operations for several years. One concept tested is the Surface Operation Automation Research (SOAR) concept, which provides solutions for surface-traffic management for both air traffic automation and flight deck systems to enhance operational efficiency in complex airport environments. An initial evaluation indicated that the concept could significantly reduce taxi delays at major hub airports during busy hub-and-spoke operations.

NASA has also developed two capabilities with the potential to improve the efficiency of departure release operations. One capability, Departure Release Communications, provides for electronic communications between tower and en route traffic management coordinators (TMCs). The other capability, Departure Release Calculator, provides a decision aid to the TMCs for determining if the release time requested by the tower controller would be acceptable; if the release time is not acceptable due to overhead congestion, the calculator offers a suitable departure release time. Reduced communications waiting time and reduced mental calculations associated with release times are expected.[1][4]

Another NASA research project designed to increase the efficiency of surface operations is the Surface Management System (SMS) concept, which advises airlines, ramp controllers, and air traffic control on push-back and taxi navigation. A runway incursion prevention concept (RIPS) has been developed and tested to provide an extra margin of safety to runway and taxi operations.

NASA has also recently initiated research on improved algorithms for conflict detection and resolution as well as pilot display concepts for final approach, landing, taxi, and departures phases of flight. The study will develop resolution advisories to prevent collisions in the terminal area. The use of data link for taxi clearances will be explored, and the availability of data from various sources (other aircraft, ADS-B, ASDE-X, etc) will be investigated. Both computer simulations and piloted simulation tests are planned.[16][17]

NASA has also developed the Expedite Departure Path (EDP) decision support tool aimed at providing Terminal Area Radar Approach Control (TRACON) Traffic Management Coordinators (TMCs) with pertinent departure traffic loading and scheduling information and radar controllers with advisories for tactical control of terminal area departure traffic. One of the proposed features of EDP is to provide departure controllers with the ability to perform unrestricted climbs where procedures typically restrict departures below incoming arrival traffic streams. The potential benefits of this feature include reductions in time-to-climb, fuel burn, and aircraft noise.[18]

To specifically address the unique characteristics of metroplex operations, NASA currently sponsors metroplex research through a number of universities and research organizations. This research is designed to better define and characterize metroplex operations and their inherent interdependencies, and to develop models and concepts for solutions to metroplex constraints. Research led by Mosaic ATM is focused on general observations, qualitative definition, interdependencies, and coordination methods. Georgia Tech and Metron are both engaged in analyzing and contrasting three TRACON operations (Southern California, New York, and Atlanta), conducting a quantitative analysis of metroplex operations, and developing associated metrics with which to compare metroplexes. Finally, multi-faceted studies led by George Mason University include development of a standard methodology to characterize the topology and interactions among and within metroplex airports; an empirical model to illustrate the consequences of alternative congestion management schemes on airlines, airports and passengers; and a set of cost effective approaches most likely to positively impact overall capacity/use of New York and California metroplexes.

Research Sponsored by Other Agencies or Organizations

Researchers at MIT Lincoln Laboratory have developed the Route Availability Planning Tool (RAPT) to handle delays that typically arise under bad weather conditions. RAPT compiles weather data from multiple sources, predicts which paths are most likely clear as the storm passes, and displays the information to the air traffic controller for departure decision making. A prototype is being tested in New York where delays have been reduced by 2300 hours, which equals \$7.5 million in operational cost savings.[5]

Research at the Volpe National Transportation System Center has focused on, among other things, the human factors issues and challenges associated with traffic flow management. Potential issues were identified for efforts aimed at enhancing airport and departure flow management. Research on two current systems (Departure Spacing Program or DSP and Airport Resource Management Tool or ARMT) focused on the requirement for controllers to manually swipe bar coded flight strips to indicate when a flight receives its taxi clearance, after it begins to taxi (DSP), and after it joins the runway queue. It concluded that doing so briefly diverts the controller's eyes from scanning the airport surface, and the procedure is potentially subject to delay or omission, particularly when controller workload is high. It also concluded that displays intended for tactical air traffic control should remain available to traffic managers so that they can continue to use them to identify gaps for departures to enter the overhead traffic flow and to monitor sector workload, and that it may be beneficial to expand their range to include more airspace so that gaps can be identified farther away. Also, that traffic information presented to the control room floor should not conflict with the information provided to the Traffic Management Unit (TMU) when it is intended to support the same functions (i.e., assessment of sector workload and the need for traffic management initiatives).[14][15]

In Europe, the German Aerospace Center DLR has performed research exploring new concepts for coordinating arrival and departure traffic management. The coordination takes into account both the departure traffic situation on the ground and the arrival situation in the terminal area. A cooperative local resource planner has been developed as a total operations planner, designed to be a decision support tool especially for departure traffic management. Evaluations conducted as part of the research show that departures are handled more punctually, while arrivals may be slightly delayed.[2][3]

Sensis Corporation has proposed a 4D trajectory departure traffic flow management concept that utilizes user-preferred trajectories. The focus of this proposal is on departure flow management and addresses inefficiencies due to congestion of voice frequency, multiple requests not handled, and quality of time estimates that cause aircraft to be manipulated by ATC to fit into the en route flow. An enhanced departure release process and decision support concept will be developed for flight testing.[6][12]

Prior NASA research has focused on the efficient and safe management of runway surface operations. Much of the work dealing with efficiency has been done in a simulated single-airport environment, and the concepts explored have had only their primary effects explored. Prior research in safe surface operations has taken the work to the flight test stage, but once again, only in the single-airport environment. The current research, being conducted under Airspace Systems Program contracts, is looking more broadly at multi-airport issues and constraints of selected major metropolitan metroplexes. Both prior and current studies will be valuable in assessing where critical traffic management constraints exist in the major choke points of the air transportation system and determining where research funding should be applied.

Further research should be guided by a systems approach: defining the issues and problems to be addressed, defining the concept and system requirements, defining the appropriate operational environment for testing concepts and solutions, bringing the arrival and departure traffic management research together, and finally, integrating previously developed and new concepts aimed at eliminating departure delays. NextGen ConOps and research plans should be reviewed to assure the NASA research is integrated and contributing to national needs.

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